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PROVISIONAL APPLICATION FOR PATENT COVER SHEET

This is a request for filing a PROVISIONAL APPLICATION FOR PATENT under 37 CFR 1.53 (c).

Express Mail Label No. EV060611279US

INVENTOR(S)

Given Name (first and middle [if any])	Family Name or Surname	Residence (City and either State or Foreign Country)
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☐ *Additional Inventors are being named on the ___ separately numbered sheets attached hereto*

TITLE OF THE INVENTION (280 characters max)

DARK FIELD INSPECTION SYSTEM FOR DEFECT DETECTION ON SEMICONDUCTOR WAFERS

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ENCLOSED APPLICATION PARTS *(check all that apply)*

☒ Specification *Number of Pages* 18 ☐ CD(s), Number

☐ Drawing(s) *Number of Sheets* ☐ Other (specify)

☐ Application Data Sheet. See 37 CFR 1.76

METHOD OF PAYMENT OF FILING FEES FOR THIS PROVISIONAL APPLICATION FOR PATENT *(check one)*

☐ Applicant claims small entity status. See 37 CFR 1.27.

☒ A check or money order is enclosed to cover the filing fees

☒ The Commissioner is hereby authorized to charge filing fees or credit any overpayment to Deposit Account Number: 02-2666

☐ Payment by credit card. Form PTO-2038 is attached.

FILING FEE AMOUNT ($) $160.00

The invention was made by an agency of the United States Government or under a contract with an agency of the United States Government.

☒ No

☐ Yes, the name of the U.S. Government agency and the Government contract number are:

Respectfully submitted,

SIGNATURE [signature]

Date 9/30/2002

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Docket Number: 6317P002Z

USE ONLY FOR FILING A PROVISIONAL APPLICATION FOR PATENT

UNITED STATES PROVISIONAL PATENT APPLICATION

For

DARK FIELD INSPECTION SYSTEM FOR DEFECT DETECTION ON SEMICONDUCTOR WAFERS

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Jennifer Stewart
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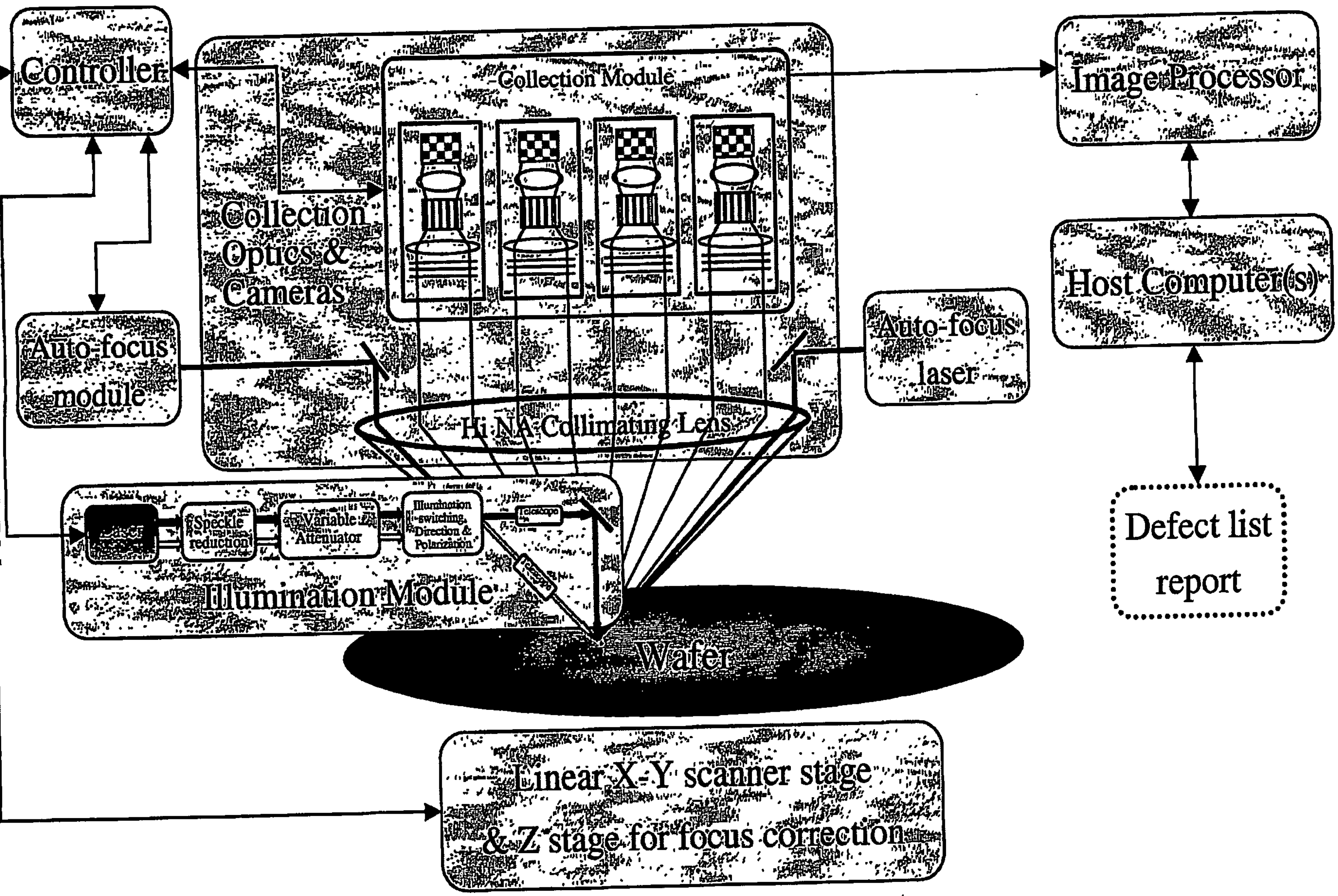
Sting Patent Application

Dark field Inspection system for defect detection on semiconductor wafers

Avishay Guetta

APPLIED MATERIALS®

Quick system overview



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APPLIED MATERIALS

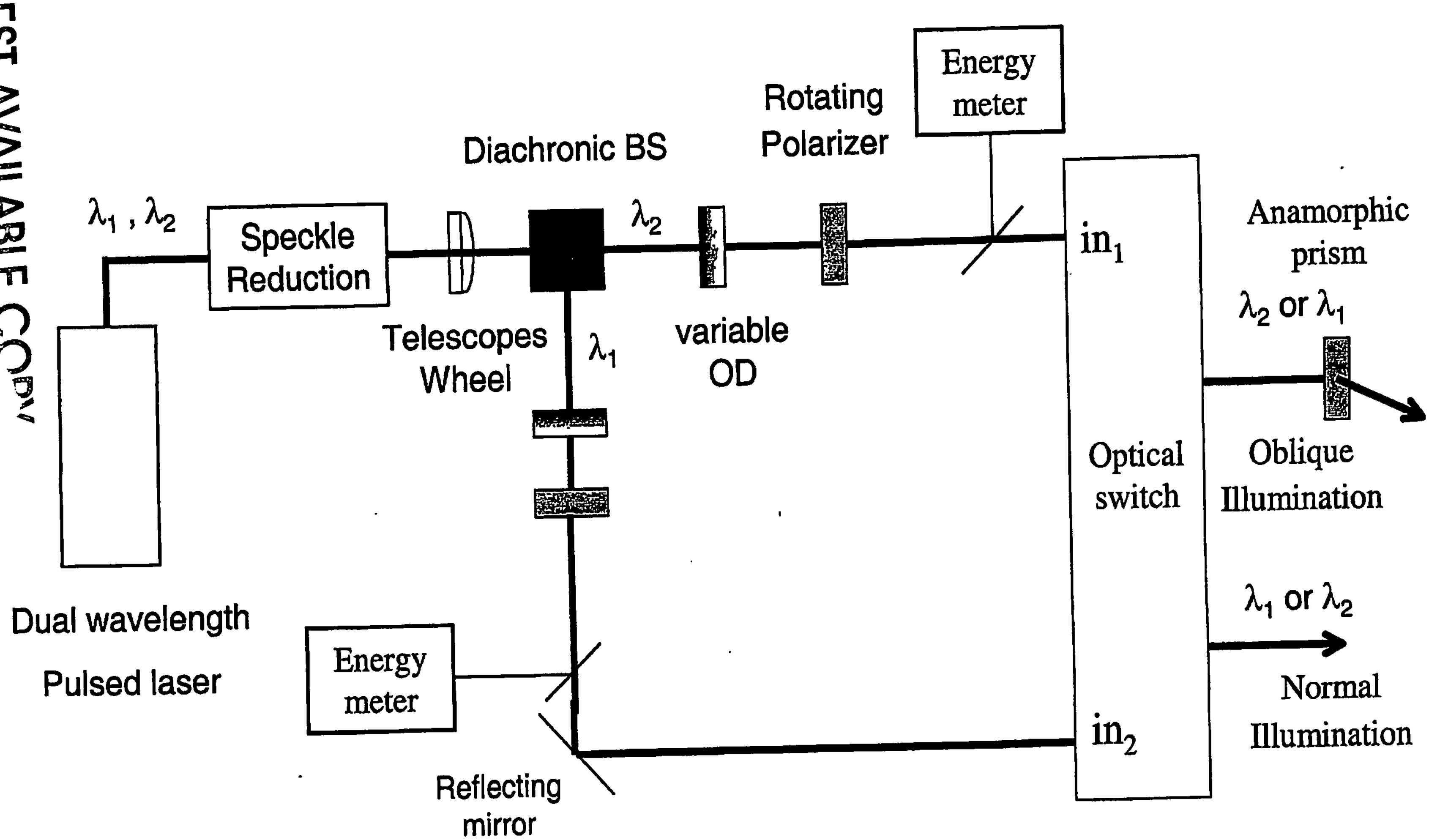
system overview

- Pulsed laser "flashes" light for short period of time.
- The laser module may emit one or 2 different wavelength of light at the same time (such as 532nm and 266nm).
- Each wavelength of light passes through the Illumination module optics. And is directed to the wafer surface either in oblique or/and normal illumination angle.
- Scattered light is collected by a high NA (Numerical Aperture) lens that image the wafer surface to the collection module. This lens can collect light with NA up to 0.98.
- Collection module composed by several 2D detectors arrays such as CCD or CMOS device. Each such detector accumulate light scattered in certain range of angles. Each detector element (CCD cell) is imaged to a certain area on the wafer – thus it collects light scattered from this area.
- The collection module is synchronized with the pulsed laser to collect light at the time of the light pulse. Received image data is converted to digital form and transformed to the Image Processing module.
- The X-Y stage move the wafer at the time of scanning in a raster line mode such that in the next laser "flash" the area that is being inspected
- Auto-Focus system measure the focus deviation and is used by the Z stage controller to correct for height deviations.
- Auto-Focus system is also used for coordinates deviation correction.

Sequence and Components

- Laser source may be: Q switched Nd-Yag with internal wavelength multiplication. The laser emits light in wavelength of 266nm and 532nm.
- Illumination beams may be directed to illuminate an area of 1x2 mm on the wafer surface.
- The collection detectors may be designed to image the illuminated area on a ~2000x1000 detector array such that the pixel size will be 1x1µm.
- The system can be operated at pulse rate of 400 light pulses/sec. Each laser pulse may be at duration of ~10ns. At that time the detectors will be adjusted for integrating light. The recorded frame can be transferred to Image Processing module.
- The stage motion will cause consecutive image frames to collect light from consecutive areas on the wafer such that the whole wafer surface is sampled for defect detection inspection.
- Each detector will pass data for Image Processing in a data rate of : 800M pixels/sec

Illumination Module – Optics scheme
Option 1



Illumination Module – components

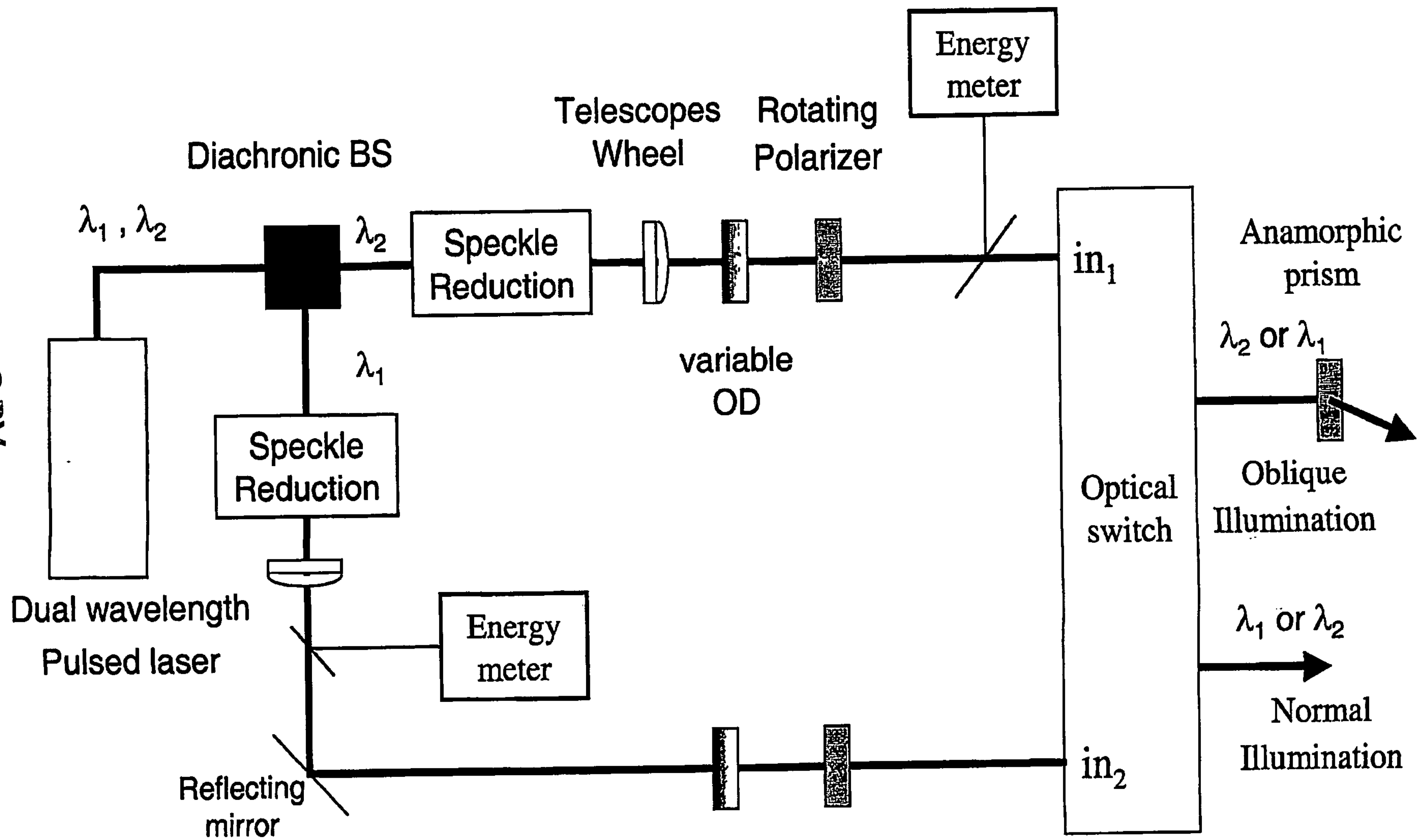
- Dual wavelength (λ_1 , λ_2) pulsed laser with external triggering emits light pulses.
- Speckles reduction module purpose is to decrease the light spatial coherence of the laser source. This operation is important for speckle elimination from the collected scattered light.
  - Methods for Speckle reductions are:
    - Fiber bundle of different lengths.
    - Use of short coherent length laser source.
    - Mode scrambling fiber bundle.
    - Appodization on collection/illumination optics.
    - Collimated speckle reduction by assembly of many beams that are not coherent with each other.
  - The Speckle reduction module may use one or a combination of these methods.
  - This module may serve as Beam Shaper in order to shape the beam energy spatial distribution as desired (uniform distribution).
- Telescopes Wheel serves as beam expander of various expanding length in order to obtain desired beam size.
- Diachroic Beam Splitter (BS) splits the dual wavelength light into its 2 wavelength components.
- Variable Optical Density (OD) attenuates the light power by variable strength in order to obtain desired light intensity pass on.
- Rotating polarizer enable control on the illumination light polarity.

Illumination Module – components cont'

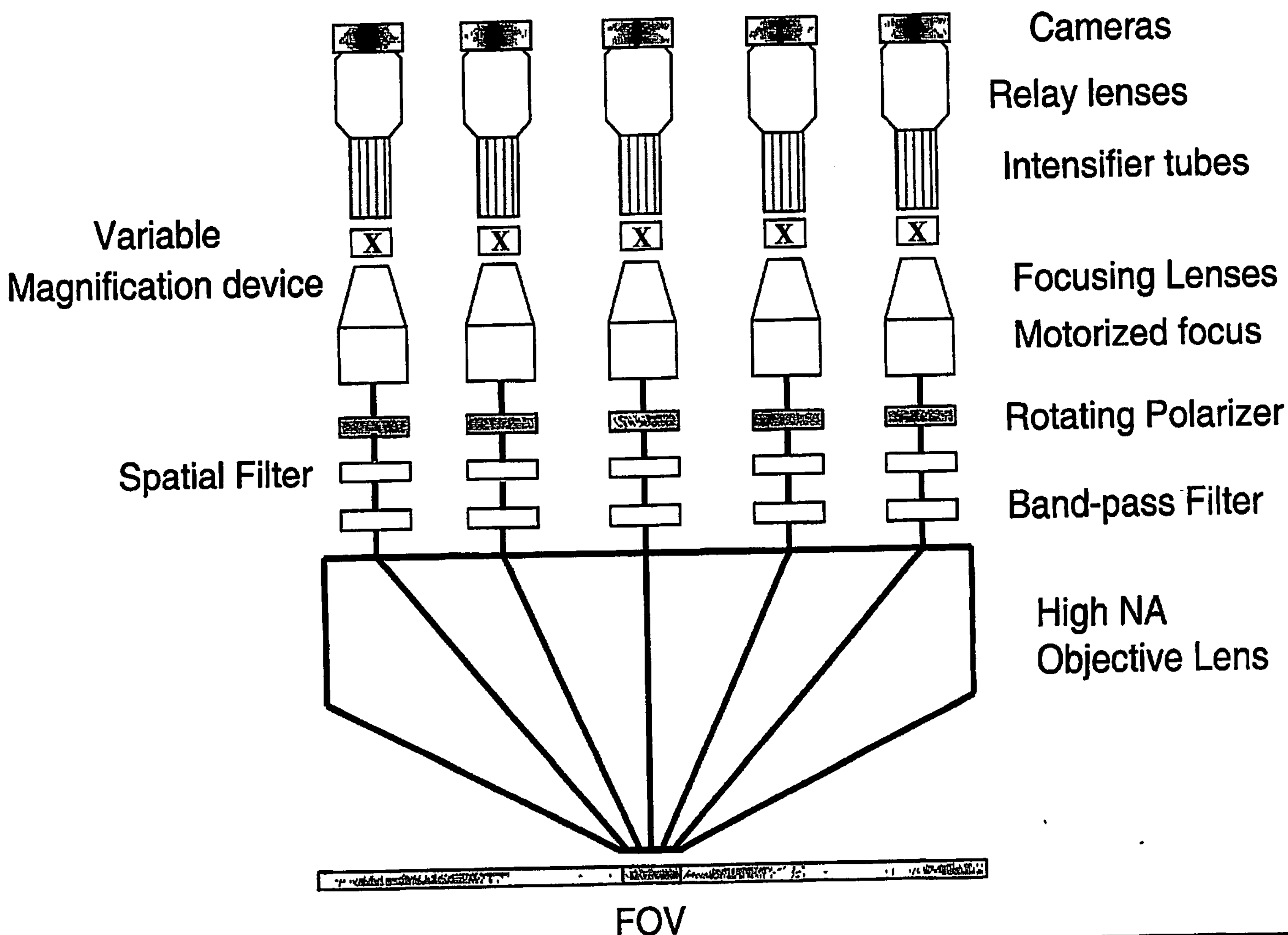
- Energy meter measure the intensity of each light pulse and is used to compensate for pulse to pulse energy deviation. Both energy meters receives small amount of laser light via a Beam Splitter.
- The Energy meter device can be used also to measure the laser pulse timing for camera synchronization and/or coordinates correction.
- Optical Switch has 2 inputs one for each wavelength. And 2 outputs, first output is directed on the wafer in normal angle of incidence, second output is directed to illuminate the wafer in oblique (5º-50º from wafer surface) angle of incidence.
- The Optical Switch may direct each input to each output. It may also eliminate one input and direct the second input to either output.
- Anamorphic prism reshapes the oblique illumination beam in order to have the same illuminated area on the wafer surface as the normal illumination beam.
- Both illumination beams may have NA in the range of 0.01-0.2

Illumination Module – Optics scheme

Option 2: Speckle reduction per wavelength



Collection module – optics scheme



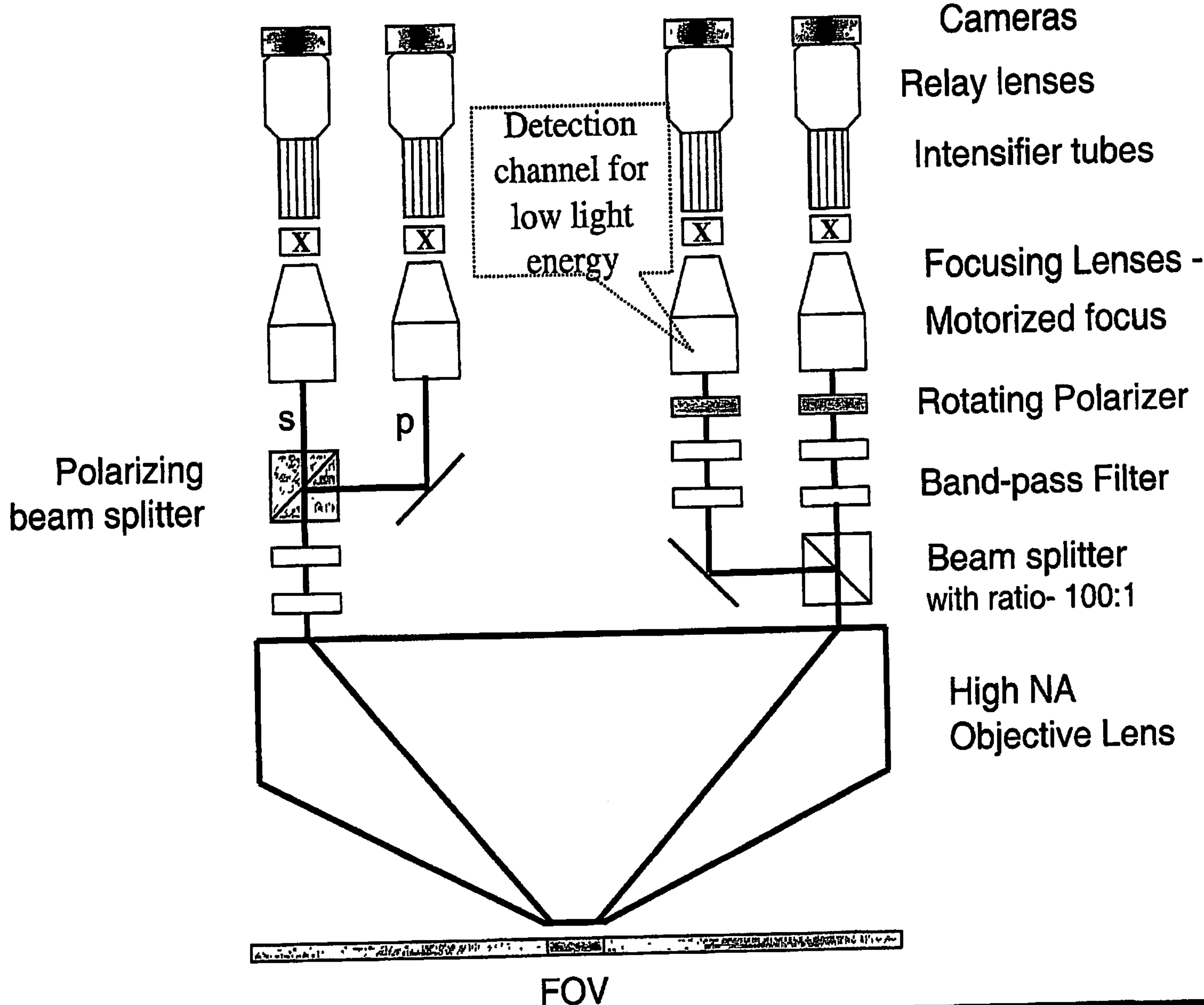
Collection module – components

- Field Of View (FOV) is the inspection area that is being illuminated and scattered light from this area is collected by the collection module.
- High NA Objective Lens collimates scattered light with NA that is up to 0.95.
- Several cameras are used, each camera receives light through its collection channel. In the above illustration 5 such channels are displayed however there may be up to 10 such channels.
- Each channel contain the following:
  - Band-Pass filter which pass a desired wavelength λ_1, λ_2 or a wavelength range that is desired for inspection. In particular the filter may pass wavelength range of fluorescence emission from the inspected surface. For example, organic materials emits light in wavelength of ~400nm when illuminated at wavelength of 266nm. Thus a Band-Pass around 400nm will cause the detection channel to be sensitive for defects of organic material.
  - Spatial Filter is a variable shape light stopper that limit the collection angle of each channel. It is well known that repetitive pattern produce diffraction lobes when illuminated by monochromatic light. This spatial filter purpose is to block the high energy lobes from passing on into the detectors. Further on, for some applications grazing collection angles may be desired (particle sensitive) or high collection angles may be desired (pattern defects). So this filter may be arbitrary designed according to application needs.
  - Rotating polarizer may be used in order to select the collected light polarity that is being detected. For example, rough layers such as metal deposition, the use of appropriate collection polarization may improve the detection sensitivity.
  - Focusing Lenses purpose is to provide optics to focus the collected light image of wafer surface on the detector plane.

Collection module – components cont'

- Each channel contain the following (continue):
  - Variable Magnification Device magnify its input image to a desired magnification such as 1x, 3x, 10x ... the output of this stage is a magnified image. The value of magnification specify the pixel size of detector cells collection area. By means of changing the magnification value the system may control the desired sensitivity for each application.
  - Intensifier Tubes is a 2D array of image intensifiers. This component is places in the image plane where the wafer surface structure is projected. This device may be either first generation (photo-cathode and phosphor) or second generation (photo-cathode, Multichannel plating and phosphor) of image intensifiers. By the use of such a device we can achieve the following advantages:
    - Sensitivity – this device is very sensitive to low light energy (low photoelectron noise level). It may enable the system to use CMOS detector type that has poor sensitivity.
    - Wavelength conversion – the intensifier emits light in wavelength that is different then it receives. Thus way the detectors array may be designed to receive light in the emitted wavelength rather then the illumination wavelength.
    - Resolution conversion – the collection optics may have optical spatial resolution that is higher then is being sampled by the detector array. In order to follow the sampling theory as given by Nyquist low the optical system must have optical transfer function that pass only spatial frequencies that are less then half of the sampling spatial frequency. The intensifier device can be designed to obtain the desired spatial frequency range at the detector end.
  - Relay Optics transfer the Image Intensifier object plane onto the camera detector array. This module may also be used for Resolution conversion as explained above
- Camera is 2D array detector that each element receive light signal and convert it to electronic current or voltage. The electronic analog signal may be digitized to binary number and then be transferred for further processing in the Image Processing module.

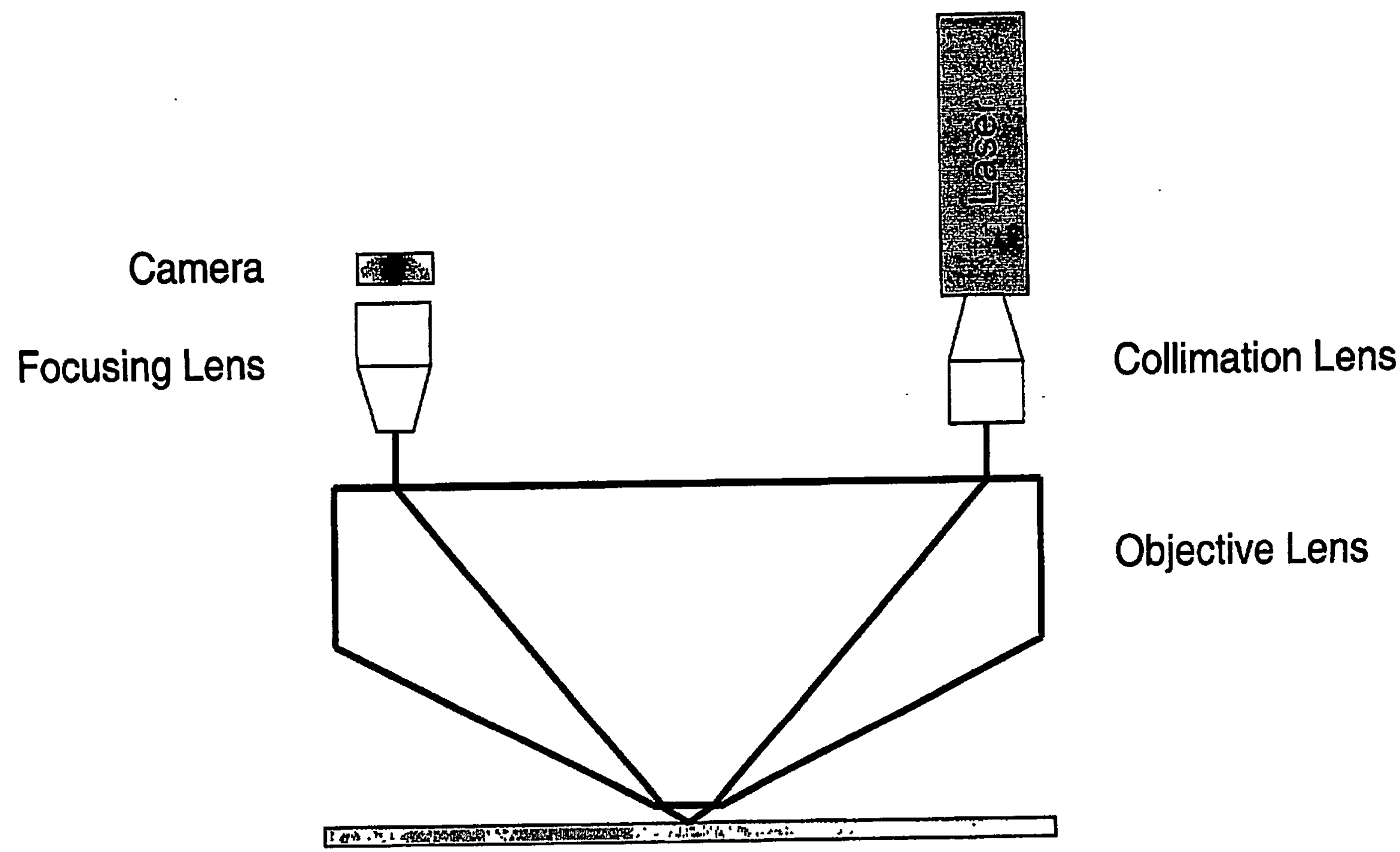
Collection module – More collection Options



Collection module – Options description

- The system can utilize the same detection perspective in two detection cannels. Where each detection cannel receives different light polarization by inserting a polarizing beam splitter in the optical path of a desired perspective (as illustrated above).
- A method for increasing the dynamic rage of certain perspective may be by using a beam splitter with high energy ratio such as 100:1. Another detection channel is designed to collect the light beam of the low energy channel. Thus way this channel may be used to detect defects in cases that the regular detection channel is saturated.
  - Another option is to use a 1:1 ratio of beam splitter and modify the band pass filter range to collect different light wavelength at the same perspective.
  - Another option is to use a 1:1 ratio of beam splitter and modify the spatial filter pass band. Thus way the system can have different channels for different repetitive patterns on the wafer.
  - The system may utilities one or a combination of the above.

Auto-focus concept

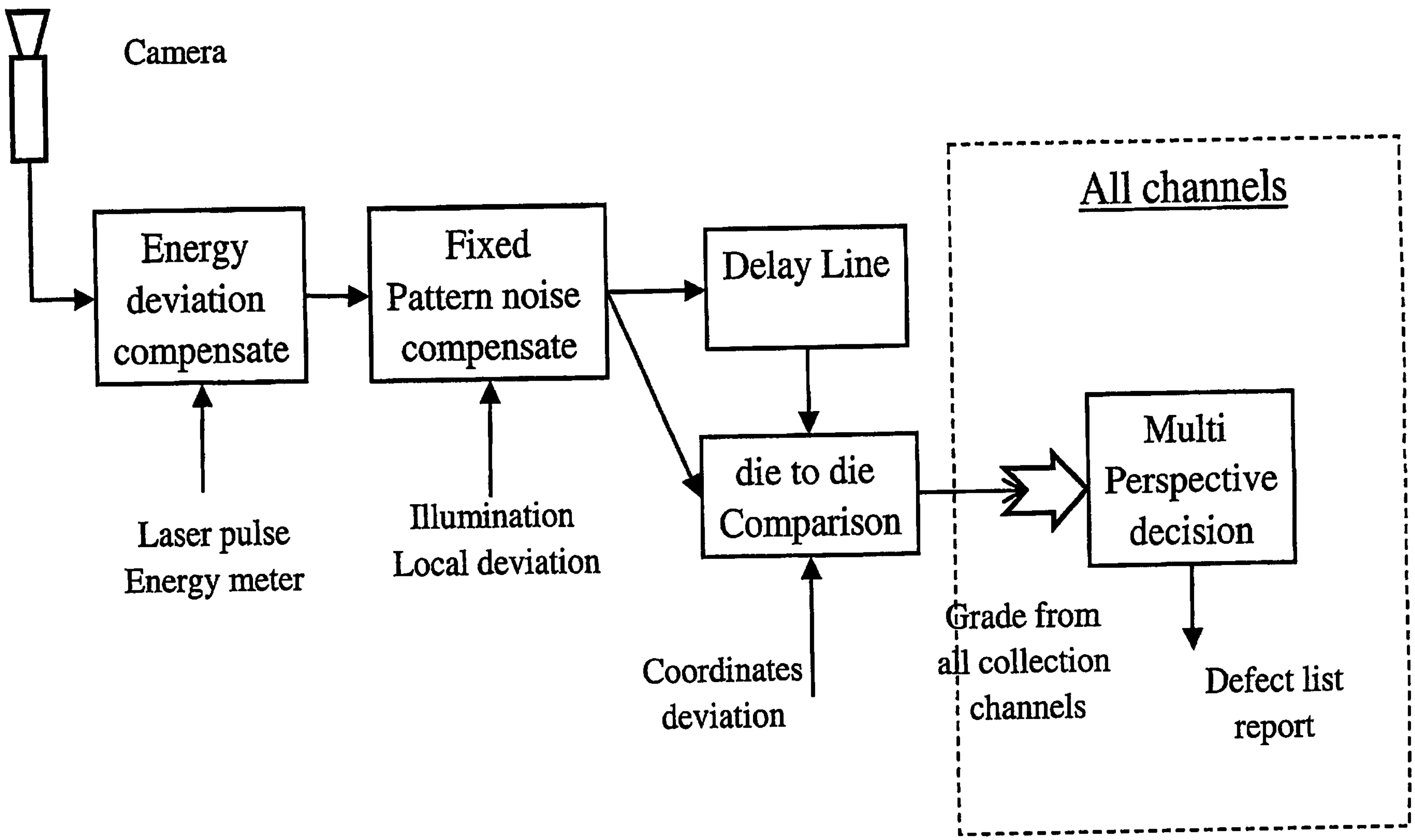


Defocus => Linear movement of the image

Auto-focus optical concept

- CW laser (LD) is imaged on the wafer from High NA lens aperture edge.
- The reflected light pass through the High NA lens and is imaged on a camera.
- The AF laser spot may be on the same area that is being illuminated by inspection. Providing that its wavelength is different then is used for inspection. Or the spot may be near the system FOV.
- Any height variation of the wafer relative to the objective plane will case the imaged AF laser position to move linearly in the camera detector array.
- The movement can be detected by means of image processing and then being translated to corresponding height.
- The measured height deviation can be used in the following ways:
  - Provide feedback to the Z stage on order to correct the height deviation.
  - Provide feedback to variable focusing optics in the collection objective.
  - Correct for coordinates deviation that is being caused due to the height variation and the grazing angle of perspective inspection.

Processing flow (one channel)



Processing flow - Components

- Camera module transfer captured 2D image in digital representation to further processing.
- Energy deviation compensate module is designed to compensate for pulse to pulse energy deviation of the laser light. It uses the energy meter reading in order to compensate for this deviation.
- Fixed Pattern noise compensate module is designed to compensate for intensity deviation of the illumination spot on the illuminated FOV. This module uses predefined data of the intensity distribution of the laser beam. The purpose of this compensation is to have uniform defect signal strength across the FOV.
- Delay line is a buffer that contains previously sampled data in the size of whole die scan.
- die to die Comparison module received corresponding images from different dies but from the same area in die coordinates. The module compare signals from both dies. Each distinguished deviation between the two dies is reported for further processing. The module receive also coordinate deviation information from other modules in the system in order to have accurate signal comparison.
- Multi Perspective decision module receives reports from all detector cannels in the system and dose the final decision regarding the analyzed region defect/non-defect. The module receives decision rules that specify thresholds and combinations for the decision process. At process completion all found defects are reported to the customer computer